

DUAL MOTION ACTUATOR

[0001] This application claims the benefit of United States Provisional Patent Application Serial Number 60/446,134 filed February 10, 2003, the complete disclosure of which is hereby expressly incorporated by reference.

BACKGROUND OF THE INVENTION

[0002] The invention is directed to an actuator which has multiple possible directions of motion.

[0003] Many different devices require multiple different senses of motion. For example, many different actuators are required for the automotive field, industrial industry, for machine tools, and the like. It would be advantageous if an actuator had multiple modes of actuation in the same unit.

[0004] One device is shown in U.S. Patent 5,045,741 where an actuator has both rotary motion and linear motion, for such uses as an automotive starter. This device has little linear motion capability as the linear motion is provided by allowing the shaft and armature to shift axially. Moreover, the linear force capabilities would be too low to achieve many functions required of such multiple motion actuation applications. Another device is shown in DE 197 55 942 where a common motor is used for a window regulator and the door close mechanism.

SUMMARY OF THE INVENTION

[0005] The objects of the invention have been accomplished by providing a drive assembly, for alternate rotational and linear output, where the assembly comprises an input power source providing rotational input; a clutch assembly having a driven portion, driven by the input power source, and at least two output driving portions, a first of the output driving portions being linear output and a second of the output driving portions being rotational output.

[0006] In another aspect of the invention, an electromagnetic clutch drive assembly, comprises a central shaft; and a ring gear assembly, rotatably mounted to the shaft. The ring gear assembly is comprised of a ferromagnetic rotor member, the rotor member having an open core portion, a ring gear positioned on an external circumferential periphery of the rotor, a bobbin of magnetic wire windings positioned within the core of the ring gear, and contacts to energize the windings to define a magnetic field. A first clutch plate is rotatably mounted to the shaft and positioned on a first side of the ring gear assembly, and is in a normally disengaged position with the ring gear assembly. A second clutch plate is rotatably mounted to the shaft and positioned on an opposite side of the ring gear assembly as the first clutch plate, and is in normal contact with the ring gear assembly. Engagement members extend between the first and second clutch plates, wherein the lateral shifting of one of the clutch plates causes the lateral shifting of the other of the clutch plates out of engagement with the ring gear assembly. Thus, the ring gear defines an electromagnet to draw one of the clutch plates into driving engagement with the ring gear, such that when the windings are energized, the one clutch plate is drawn into engagement with the ring gear and is driven by the ring gear.

[0007] In yet another embodiment of the invention, an electromagnetic clutch drive assembly, comprises a housing assembly, comprised of a main housing portion and a cover portion. A central shaft is positioned within the housing assembly. An input power source provides rotational input. An electromagnetic clutch assembly has a driven portion, driven by the input power source, and at least two output driving portions. A first of the output driving portions is linear output and a second of the output driving portions is rotational output, whereby activation of an electromagnet of said electromagnetic clutch assembly controls the output between the first and second output driving portions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The invention will now be described with relation to the drawings, where:

[0009] Figure 1 shows an exploded perspective view of the dual actuator of the present invention;

[0010] Figure 2 shows a perspective view of the main housing portion of the actuator of Figure 1;

[0011] Figure 3 shows a rear perspective view of the main housing of the actuator of Figure 2;

[0012] Figure 4 shows an upper perspective view of the actuator housing of Figures 2 and 3;

[0013] Figure 5 is an inside plan view of the main housing of Figures 2-4;

[0014] Figure 6 is a cross-sectional view through lines 6-6 of Figure 5;

[0015] Figure 7 is a perspective view of the rack used for one phase of the actuation;

[0016] Figure 8 is an underside plan view of the rack of Figure 7;

[0017] Figure 9 is a side plan view of the electric motor of the present invention;

[0018] Figure 10 is an end view of the motor of Figure 9;

[0019] Figure 11 is a perspective view of the fixed shaft of the present invention;

[0020] Figure 12 shows a perspective view of a clutch plate used for one phase of the dual actuator of the present invention;

[0021] Figure 13 is a cross-sectional view through lines 13-13 of Figure 12;

[0022] Figure 14 shows a perspective view of the bobbin, which makes up the electromagnet of the present invention;

[0023] Figure 15 shows a perspective view of the central rotor of the present invention;

[0024] Figure 16 shows a perspective view of a ring gear used in the present invention;

[0025] Figure 17 shows an exploded view of the bobbin of Figure 14, the rotor of Figure 15, and the ring gear of Figure 16, in exploded view together with slip rings;

[0026] Figure 18 shows a second clutch plate used with a second phase of the dual actuator;

[0027] Figure 19 shows a cross-sectional view through lines 19-19 of Figure 18;

[0028] Figure 20 shows a perspective view of the return spring;

[0029] Figure 21 shows a cross-sectional view through lines 21-21 of Figure 20;

[0030] Figure 22 shows a perspective view of the end cover of the present invention;

[0031] Figure 23 shows a perspective view of the brushes used with the present invention;

[0032] Figure 24 shows a perspective view of the connector housing of the present invention;

[0033] Figure 25 is a rear perspective view of the cable retainer used in the present invention;

[0034] Figures 26 and 27 are front and rear plan views of the retainer of Figure 25, respectively;

[0035] Figure 28 is a perspective view of the dual actuator in a partially assembled view less the end cover;

[0036] Figure 29 is a perspective view of the assembly less the main housing portion;

[0037] Figure 30 is a perspective view similar to that of Figure 28, showing full assembly;

[0038] Figure 31 shows a side plan view of the fully assembled dual actuator;

[0039] Figure 32 shows an end view of the actuator of Figure 31;

[0040] Figure 33A shows a cross-sectional view through lines 33-33 of Figure 31;

[0041] Figure 33B shows a cross-sectional view similar to that of Figure 33A, showing the other phase of actuation;

[0042] Figure 34 is a cross-sectional view through lines 34-34 of Figure 31;

[0043] Figure 35 shows a top perspective view of another embodiment of the invention;

[0044] Figure 36 shows an inside perspective view of the housing portion of the embodiment shown in Figure 35;

[0045] Figure 37 shows another perspective view of the housing portion of Figure 36;

[0046] Figure 38 shows an outer perspective view of the housing portion of Figures 36 and 37;

[0047] Figure 39 shows an inside perspective view of the cover portion for the embodiment shown in Figure 35;

[0048] Figure 40 shows an outside perspective view of the cover portion shown in Figure 39;

[0049] Figure 41 shows an exploded view of the electromagnetic clutch assembly of the present embodiment;

[0050] Figure 42 shows an exploded view of a portion of the assembly of Figure 41;

[0051] Figures 43 and 44 show an enlarged view of the clutch plates of the electromagnetic clutch assembly of Figure 41;

[0052] Figure 45 shows an enlarged perspective view of the rotor and ring gear of the clutch assembly shown in Figure 41;

[0053] Figure 46 shows an enlarged view of the rotor member shown from the opposite side as that of Figure 45, and with the ring gear removed;

[0054] Figure 47 shows an enlarged view of the shaft which is installed in the housing portion shown in Figures 36 and 37;

[0055] Figure 48 shows an enlarged view of the compression spring shown in Figure 41;

[0056] Figure 49 shows an enlarged view of a control board;

[0057] Figure 50 shows an enlarged view of the motor drive assembly;

[0058] Figure 51 shows the motor, control board and clutch assembly installed in the housing member, with the cover portion removed;

[0059] Figure 52 shows the housing control board and clutch assembly installed in the cover portion with the housing portion removed;

[0060] Figure 53A is a cross-sectional view taken through lines 53-53 of Figure 2 in the normally operated position, where the electromagnet is not operated;

[0061] Figure 53B is a view similar to that of Figure 53A with the electromagnet energized; and

[0062] Figure 54 is a cross-sectional view through lines 54-54 of Figure 35.

DETAILED DESCRIPTION OF THE INVENTION

[0063] With respect first to Figure 1, the present invention relates to a dual actuator, which can operate in two separate phases. That is, with one actuator, two different and separate modes can be operated as described herein. As shown in Figure 1, the dual actuator is generally referred to as reference numeral 2, which comprises a main housing portion 4 having a mounting flange 6 for attaching an electric motor 8. Housing 4 also includes an integrated slide 10 for receipt of a rack 12, which in turn is fixed to a bowden cable 14. A central shaft 16 is fixedly mounted in main housing 4 and coaxially receives the dual clutch assembly referred to generally as 18. The assembly 18 is comprised of first clutch plate 20, thrust washers 22, which sandwich a thrust bearing 24, together with a thrust washer 25. The assembly 18 further includes bobbin 26, rotor assembly 30, thrust rods 32, thrust washer 34, split lock ring 36, thrust washers 38, thrust bearing 40, second clutch plate 42, and return spring 44. An end cover 46 completes the assembly, as will be described herein. Finally, a brush plate assembly 48 is included, which also will be described further herein.

[0064] With respect now to Figures 2-6, the main housing portion will be described in greater detail. As shown in Figures 2 and 3, housing portion 4 includes mounting flange 6 having a mounting face 60 with tapped mounting apertures at 62. The mounting flange 6 opens to an enlarged cavity portion 64 and further includes an opening 66, which communicates between the flange portion into an inner cavity portion 68 of the housing portion 4. The inner cavity portion 68 is generally defined so as to receive the clutch assembly 18 (Figure 1) and therefore takes on a generally cylindrical configuration by way of cylindrical wall 70, which upstands from and is integrated with rear wall 72. Cylindrical wall 70 includes mounting ears 74, 76, 78, and 80, including representative mounting apertures 82, tapped apertures 84, and locating dowel apertures 86.

[0065] Cylindrical wall 70 is interrupted on one side to form an opening at 90, which is generally defined by side wall portion 92 having an aperture 94 therethrough, edge portion 96, and a generally planar edge at 98 having tapped mounting apertures 100, as further described herein. As shown best in Figures 2 and 4, rear wall 72 further includes a central opening 104, which includes a first diametrical portion 106 extending rearwardly to outwardly projected face 108, and a second diametrical portion 110, which extends inwardly to face 112. As shown best in Figures 3 and 4, diametrical portion 110 is a machined section internal to a post section 114, which extends transversely of rear wall 72. It should also be noted that post section 114 intersects the guide member 10, which houses rack 12. Post section 114 has a central aperture 116, which extends from an exterior, as shown in Figure 3, and extends inwardly through face 112, as shown in Figure 4.

[0066] With respect now to Figures 4-6, diametrical portions 106 and 110 intersect a guide channel 118 through the guide member 10 to form a common area. As best shown in Figure 3, the guide member 10 includes a cable-receiving opening at 120, including an enlarged opening portion 122 and a cable-receiving portion 124. A mounting aperture is positioned at 126, which will be described further herein. Finally, as best shown in Figure 2, the inner wall 72 includes a plurality of integral raised radial ribs 130 radially disposed around diametrical portion 106, as will be further described herein.

[0067] With respect now to Figures 7 and 8, rack member 12 is shown as a generally linear rack and includes side walls 140 and top wall 142, including a cable-receiving opening 144 having enlarged portion 146 and a cable-receiving portion 148. Rack member 12 further comprises a plurality of rack teeth 150 on the side opposite face 142. It should be appreciated that the general profile of linear rack 12 is such that it is received in guide channel 118 in guide member 10.

[0068] With respect now to Figures 9 and 10, motor 8 is generally comprised of a motor section 160 having a shaft 162 with mounting apertures 164 and a shaft section 166 having splined teeth 168.

[0069] With respect now to Figure 11, central shaft 16 is shown having a first diametrical section 170, with an enlarged diametrical section at 172, thereby defining shoulder 174. An end face of diametrical section 170 includes a tapped aperture (shown in phantom) at 176. Shaft 16 further includes diametrical section 178, which together with diametrical section 172 forms shoulder 180. Diametrical section 178 further includes an undercut channel at 182 to receive retaining ring 36, as will be described further herein.

[0070] With respect now to Figures 12 and 13, first clutch plate 20 is shown, which is generally comprised of a clutch plate 190 and a spur gear 192. Clutch plate 190 includes a face 194 having a plurality of radially arranged recesses 196 in a matching array to radially arranged ribs 130 (Figure 2). Clutch plate 20 further includes a raised diametrical portion 198 having an outer diameter 200 slightly smaller than diametrical opening 106 (Figure 5). Clutch plate further includes on the opposite side, rear face 202 having an annular recess at 204, which communicates with throughbore 206. It should also be appreciated that throughbore 206 is generally profiled to be rotatably received on diametrical portion 172 (Figure 11) of shaft 16. It should also be appreciated that the teeth of spur gear 192 are generally sized for meshing engagement with teeth 150 of rack 12 (Figure 7).

[0071] With reference now to Figure 14, bobbin 26 is shown having outer flanges 210 and an inner spool portion at 212. It should be appreciated that

bobbin 26 is profiled to receive a plurality of windings of magnet wire, as will be further described herein. With respect now to Figures 15-17, rotor assembly 30 is shown as including rotor 220, ring gear 222 and slip rings 224. As shown in Figure 15, rotor 220 includes a central wall portion 230 having a hub 232 extending outwardly therefrom, together with a cylindrical wall 234. Central hub portion 232 includes a recessed face at 236 extending inwardly from the end of hub 232, which further includes apertures 238 and a central bore at 240. Cylindrical wall 234 includes an inner surface at 242 with apertures 244 extending entirely through the wall, as will be described in greater detail herein.

[0072] With respect now to Figure 16, ring gear 222 includes a cylindrical ring portion 250 having an inner diameter, which is interferingly fit with the outer diameter of rotor portion 220. Ring 22 further includes a central integral ring gear portion 252 flanked by bands 254. Apertures 256 extend through ring 250, as shown in Figure 16, and are positioned to open onto bands 254, as well as are profiled to match apertures 244. With reference again to Figure 17, it should be appreciated that the inner diameter 214 of bobbin 26 is profiled for interferingly fitting over hub 232, that ring 250 is profiled for interferingly fitting over cylindrical wall portion 232 (with apertures 244 and 256 aligned), and that slip rings 224 are profiled for receipt over band portions 254. Preferably, the ring gear is formed from an insulating material, such as a plastics material, for reasons which will become clear, as discussed herein.

[0073] With respect now to Figure 18, second clutch 42 generally includes a clutch plate 260 having a front face 262 and a rear face 264. As shown in Figure 18, front face 262 includes a plurality of recesses 266 and a recessed portion at 268. The recessed portion 268 surrounds a diametrical portion 270, which projects gear portion 272 forwardly therefrom. As shown in Figure 19, clutch 42 includes an annular recess at 274 coaxially disposed relative to a through bore at 276.

[0074] With reference now to Figures 20 and 21, return spring 44 is shown as a stamped and formed disk of spring material, which includes an outer annular flange portion 280, an inner annular ring section at 282, and individual spring legs

284, which extend between the two. It should be appreciated that in the cross-sectional view of Figure 21, spring member 44 is shown in its free state, where ring portion 282 and flange 280 are spaced apart, but as shown further herein, this annular spring can deflect such that the vertical distance between ring 282 and flange 280 is reduced.

[0075] With respect now to Figure 22, end cap 46 is shown including a mounting face 290, mounting ears 292, 294, and 296, with apertures 298 being positioned for mounting cover 46 and dowel openings 300 for locating the cover relative to housing 4, as further described herein. Cover 46 also includes a diametrical recess 302, which extends rearwardly to define face 304. Face 304 includes an undercut recess at 306 to defined face 308. Finally, cover 46 includes an annular opening at 310, which is generally profiled to receive hub portion 270 (Figure 18) therethrough.

[0076] With respect now to Figure 23, a brush plate is shown as 320, including a transverse bar portion 322 having apertures 324 therethrough. Bar 322 includes brush contacts 326 extending therefrom with rounded contact portions at 328. The opposite end of bar portion 322 includes stamped and formed contacts 330, which together form pin contacts, as described herein. Finally, as shown in phantom, an intermediate portion is shown at 332, which will be later removed to separate the two contacts. In the preferred embodiment of the invention, contacts are made from a highly conductive material, such as beryllium copper, but other materials or alloys could also be used. With respect now to Figure 24, brush plate assembly 48 is shown with an overmolded housing portion 340 having a cover portion at 342 having apertures 344, 346 therethrough, and an integral connector housing portion at 348. Connector terminal portions 330 are positioned within the connector housing portion 348, and terminal portions 326 extend downwardly from the connector portion 348 but are not encapsulated within the plastic.

[0077] With respect now to Figures 25-27, a cable-retaining member 350 is disclosed having a generally square body portion at 352 and an outer flange 354. A slot 356 extends the entirety of the length of the retainer 350 and intersects a

cylindrical aperture 358, which extends only part way along body portion 352, forming shoulder 360. With the components as described above, the assembly of the device will now be further described.

[0078] With reference again to Figure 1, bowden cable 14 is shown as including outer sheath 370 having an internally movable cable 372 having an end ball 374 for gripping the cable 372. The assembly begins by placing the cable 372 into slot 356 of retainer 350 (Figures 25-27) with the end of the sheath 370 abutting shoulder 360 of the retainer. This positions the end ball 370 proud of the retainer 350, whereupon ball 374 can be positioned in opening 146 of rack 12 (Figure 8) with the remaining cable portion 372 positioned in slot 148. The rack 12 and the retainer 350 can thereafter be slidably received into opening 118 (Figure 3) of guide 10. A retaining screw or fastener can thereafter be placed into tapped hole 126 (Figure 3) to keep the retainer 350 and cable 14 in place. It should be appreciated that this places rack teeth extending downwardly and intersecting with diametrical portion 110.

[0079] Motor 8 is now mounted to flange 6 by positioning motor shaft 166 and gear teeth 168 through flange opening 66 and by aligning apertures 164 of flange 162 (Figure 10) with apertures 62 (Figure 2). Shaft 16 is now mounted in aperture 116 by way of a threaded fastener into tapped hole 176 (Figure 11). Clutch plate 20 can now be positioned over shaft 16, such that opening 206 (Figure 3) is positioned over diametrical portion 172 (Figure 11). This also allows teeth 192 to mesh with teeth 150 on rack member 12. This also allows, when clutch plate is pushed fully forward and radially aligned, that radial ribs 130 engage within respective recesses 196. The thrust washers 22, sandwiching thrust needle bearing 24, can now be positioned over shaft 16 and received in diametrical recess 204 (Figure 13). Finally, thrust washer 25 is slidably received over shaft 16 and abuts with shoulder 180 (Figure 11) of shaft 16.

[0080] The assembly of the rotor subassembly can now be completed, where magnet wire is wound on bobbin 26, wherein a start lead is held exposed from the bobbin and a plurality of turns are made exposing another end of the lead. Ring gear 26 is now positioned over hub 220 into an interfering fit therewith.

It should be appreciated that the apertures 244 and 256 of the rotor and ring gear are aligned. Bobbin 26 may now be positioned over hub 232 of rotor 220, with the two leads extending through apertures 244 and 256. This places the leads onto the outer surface of bands 254. The slip rings 220 may now be positioned over the bands 254 such that the magnet wire is welded to, soldered to, or is in some way electrically interconnected with the magnet wire. As mentioned before, the ring gear 26 is formed of an insulating material, whereas the slip rings 224 are comprised of a copper alloy, and therefore the slip rings are interconnected to opposite ends of the wire.

[0081] This assembly, that is, rotor assembly 30, together with bobbin 26, may now be slidably received over shaft 16 with the bobbin end in first. The thrust rods are now positioned in apertures 238 (Figure 15) until the thrust rods abut outer thrust washer 22 (Figure 1). A thrust washer 34 is now slidably received over the diametrical portion 178 (Figure 11) of shaft 16, and a snap ring 36 is positioned in groove 182. Thrust washers 38 are now positioned on opposite sides of another thrust needle bearing 40 and are slidably received over shaft 16. The outer clutch plate 42 is now slidably received over shaft 16 until it abuts rotor assembly 30. Return spring 44 is now positioned adjacent to clutch plate 42, with outer flange 280 (Figure 21) residing in recessed portion 268 (Figure 18). The assembly to this point is shown in Figure 28. Cover 46 is now positioned adjacent to spring 44 and with corresponding mounting ears 292 positioned adjacent to mounting ears 78, and with mounting ears 294, 296 adjacent to mounting ears 76, 74, respectively (Figures 2 and 22). It should also be appreciated that dowl pins can be positioned in corresponding aligning apertures, that is, apertures 300, 86, in each of the mounting ears 74, 78, 292, 296, to align the housing 4 and cover 46 together.

[0082] The assembly is completed by placing the brush assembly 48 over opening 90, such that openings 344 are aligned with openings 100, and openings 346 are aligned with openings 311 (Figure 1). The completed assembly is shown in Figures 30-32.

[0083] With the device as described above, the operation will now be described relative to Figures 33A, 33B and 34. As shown in Figure 33A, rotor member 220 will be locked in the axial position relative to shaft 16. That is, rotor 220 does not laterally move to the left or right as viewed in Figure 33A. It is locked on one side by thrust washer 25 (Figure 1) and on the opposite side by thrust washer 34 (Figure 1). However, clutch plates 20 and 42 move laterally relative to shaft 16, as described below.

[0084] As shown in Figure 33A, the electromagnet formed by bobbin 26 is not operational, and therefore spring 44 is fully sprung to its right, forcing clutch plate 42 away from cover 46. This causes thrust washers 38 (Figure 1) to push on push rods 32 and thereafter onto thrust washers 22 (Figure 1), thereafter pushing clutch plate 20 into wall 72. This causes the inter-engagement of radial ribs 130 (Figure 2) with recesses 196. Thus, clutch plate 20 is locked in place, while clutch plate 42 is frictionally held against rotor 220 by spring 44. Thus, when motor shaft 166 and gear teeth 168 rotate, thereby causing rotor 220 to revolve around shaft 16, it carries with it clutch plate 42, thereby turning gear teeth 272. Thus, gear teeth 272 are one phase of the dual phase actuator, and can operate any member operable by way of connection to gear teeth 272..

[0085] When the alternate phase is desired, that is, when the feature connected to the bowden cable 14 is desired, the magnet is actuated, by supplying power to contacts 330 (Figure 28). This supplies a current through contacts 326, slip rings 224 and thereafter to the magnet wire, which is wound around bobbin 26. The flow of current is such as to create a magnetic field forcing clutch plate 20 from the position shown in Figure 33A leftward to the position shown in Figure 33B, where a gap exists between clutch plate 20 and inner surface 72. This releases the previous inter-engagement of ribs 130 and recesses 196, and at the same time, causes push rods 32 to move leftwardly, engaging thrust washers 38 (Figure 1) and causing the engagement of clutch 42 with inner wall 304 and the inter-engagement of ribs 312 (Figure 22) and recesses 266 (Figure 18). Thus, clutch plate 42 is locked in place from rotating about shaft 16, whereas clutch plate 20 is released from engagement with surface 72, and is attached to rotor 30 through the electromagnetic connection. Thus, actuation of

the motor and gear teeth 168 causes a rotation of rotor assembly 30 and clutch 20, which in turn drives linear rack 12 and bowden cable 372.

[0086] While the invention disclosed herein shows rotary and linear outputs, it should be apparent that two rotary outputs, or two linear outputs could also be easily provided. For example, if two rotary outputs are required, then the output directly from clutch plate 20 could be used. Also, if two linear outputs are desired, then a second rack assembly could be provided at the second clutch plate 42.

[0087] With respect now to Figures 35 through 54, another embodiment of the invention will be described. As best shown in Figure 35, a dual actuator is shown generally at 402 having a main housing portion 404. As shown in Figure 51, main housing portion 404 includes a motor mounting section 406 to mount a motor 408. As shown in Figure 35, cover 404 includes an integrated slide portion 410 profiled to receive a rack 412 (Figure 52), which moves bowden cable 414. As shown in Figure 51, a shaft 416 receives an electromagnetic clutch assembly 418 for rotation thereon.

[0088] With reference now to Figure 41, electromagnetic clutch assembly 418 includes first clutch plate 420, contact ring 421, snap ring 423, washer 425, bobbin 426, rotor assembly 430, thrust rods 432, snap ring 436, contact ring 437, second clutch plate 442, thrust or compression spring 444, and thrust washers 445. With reference again to Figure 35, cover portion 446 encloses the assembly to provide an enclosed motorized dual actuator, dual clutch assembly, whereby alternative linear or rotary motion can be provided. Finally, and with reference again to Figure 51, the assembly generally includes a control circuit board at 448, as will be described herein. With the general elements of the second embodiment now described, the details of the components will now be described.

[0089] With reference first to Figures 36 and 37, main housing 404 is shown, where motor mounting section 406 is generally defined by an enlarged volume portion at 450, flanked by bearing wall portions 452, 454. A coupling receiving section 456 is also provided, which is continuous with a bearing wall 458, a worm gear receiving section 460, and a bearing receiving section 462.

[0090] With reference still to Figures 36 and 37, main housing portion 404 includes a cavity portion 468 profiled to receive the clutch assembly 418. As shown, shaft 416 is centrally located relative to the cavity 468, and is integrally molded into the main housing portion. That is, in this embodiment, shaft 416 is comprised of a metal shaft, preferably a steel alloy, where the shaft end is integrally molded into a plastic housing. As shown, cavity 468 is defined by an outer diameter portion 470 and an inner face 472, having a plurality of radially spaced apertures 474, radially spaced about the center of shaft 416. Housing 404 further includes an inner radius portion 476 and an opening portion, which communicates into the rack slide 410, in a similar manner as described with the embodiment of Figures 1 through 34. Main housing portion 404 further includes a plurality of mounting bosses 480 and an outer peripheral edge 482 profiled to receive a peripheral gasket. Main housing portion 404 includes a port 484, which communicates with the inner cavity 406 for control of the motor and clutch, as will be described herein. Finally, with respect to Figure 38, the main housing portion 404 is shown from the exterior side, where a central hub portion 486 is shown, which would be overmolded about the end of shaft 416.

[0091] With respect now to Figure 39, cover portion 446 is shown having a cavity portion 496 complementary with the cavity portion 406 in the main housing portion 404 (Figure 6) and complementary bearing wall portions 502, 504, coupling receiving section 506, bearing receiving section 508, gear receiving section 510, and bearing receiving section 512. A clutch receiving cavity is formed at 518 having an inner diameter 520 and an internal face 522. Face 522 includes a plurality of radially spaced apertures 524. A radial face 526 is defined about an aperture 528. Cover portion 446 is shown from the exterior in Figure 40, where bosses 530 are shown, which are complementary with bosses 480 (Figure 37) on main housing portion 404.

[0092] With reference now to Figures 42, 45 and 46, rotor assembly 430 will be described in greater detail. As shown first in Figure 46, rotor assembly 430 includes a central rotor portion 540 having an outer diameter portion 542 having raised portions at 544, and a slotted portion 546 extending therethrough. A central hub portion 548 extends upwardly defining a toroidal volume at 550.

Central hub portion 548 also includes a central bore 552 having a recess 554 and three apertures 556 surrounding the bore 552. As shown in Figure 45, bore 552 extends through the entire rotor portion, and as should be appreciated, is profiled to be rotatably received on shaft 416. As best shown in Figure 46, rotor portion 540 also includes an outwardly extending edge having interlocking members 558, defined by intermittent raised portions 560 and groove portions 562. As shown best in Figure 45, rotor 540 also includes an outer face at 566 also having interlocking portions 568 defined by raised portions 570 extending upwardly from face 566. Finally, it should be understood that rotor 540 is comprised of a ferromagnetic material, such as an iron ore composition.

[0093] As shown in Figure 45, an outer ring gear is shown at 580 attached to the outer diameter portion 542 of rotor 540. In the embodiment shown, ring gear 580 is comprised of plastic, and is integrally molded to the outer diameter 542 of rotor 540 and encapsulates portions 544 in order to be fixed thereon. As shown in both Figures 42 and 45, ring gear 580 includes an inner portion 582 and an outer portion 584, where the outer portion 582 includes the ring gear teeth 586. Intermediate the inner and outer portions, annular slots 588 are defined interrupted by ribs 590 and slots 592, as will be described in greater detail.

[0094] With respect now to Figure 42, the contact ring assemblies 421 and 437 will be described, and in this embodiment, are substantially identical. As shown, each of the rings includes an outer molded ring portion 600 having an inner contact ring at 602. The contact ring 602 is formed of a conductive material, and is trapped by outer flange portions 604, 606. The outer flange portion 606 is interrupted by radial slotted portions 608, and includes a peripheral upstanding lip 610. As best shown in relation to contact ring assembly 437, the inner contact ring 602 includes a contact portion 612 extending through the slotted portion 608, and as appreciated by one skilled in the art, would be profiled to receive a terminating end of a magnet wire, as described further herein. It should also be appreciated that the slotted openings 608 are radially disposed in the same pattern as members 590 (Figure 45) and therefore contact ring assemblies 421 and 437 can be received within their associated slots 588, with the lip 610 snapping into a locked engagement with the outer ring gear 580.

[0095] With reference still to Figure 42, magnet wire assembly 426 includes a bobbin housing 620, magnet wire windings 622 having opposite terminating ends at 624.

[0096] With reference now to Figures 43 and 44, the first and second clutch plates 420 and 442 will be described. With reference first to Figure 44, clutch plate 420 includes a face portion 630 having outward projections 632 extending therefrom. Clutch plate 420 also includes a centrally located pinion 634 having a throughbore at 635, where the throughbore is profiled to be received over shaft 416, and pinion is profiled to be received into the portion 478 communicating with the rack slide 410. Clutch plate 420 further includes a rear face 636 having projections at 638. It should be appreciated that clutch plate 420 is profiled such that face 630 can be positioned adjacent to face 472 (Figure 36) and such that projections 632 can be received in apertures 474. It should be further appreciated that rear face 636 can be positioned adjacent to hub 548 of rotor 540 and that projections 638 can be engaged with the interlocking portions 558, that is, projections 638 can be received in the recesses 562 (Figure 46).

[0097] In a like manner, clutch plate 442 includes a front face 640 having projections 642 extending therefrom. Drive gear 644 extends from the front face and has a throughbore at 645. Clutch 442 has a rear face 646 with projections 648. It should also be appreciated that clutch plate 442 is profiled to be received in cavity 518 (Figure 39) with surface 640 being positionable adjacent to face 522, with projections 642 being positionable in apertures 524. It should also be appreciated that this positions drive gear 644 projecting through opening 528 and cover member 446. Finally, projections 648 are profiled to be interlockable with interlocking members 568, intermediate projections 570 (Figure 45).

[0098] With respect now to Figure 47, shaft 416 includes an outer end 650, and a splined end 652, which is profiled for integrally molding in the main housing portion 404, as described above. Shaft 416 further includes first and second peripheral grooves 654 and 656.

[0099] With respect to Figure 48, thrust washer 444 is shown. Thrust washer 444 is comprised of a unitary spring steel member profiled with projecting portions so as to define contact points at 660, thereby defining a compression spring.

[00100] With respect to Figure 49, control board 448 is shown as including a printed circuit board 670 having brushes 672 and 674 mounted thereon, and electrically connected thereto, for example, by way of terminals 676. An electrical connector 678 is mounted to the printed circuit board 670 and includes a housing portion 680 having pin terminals at 682 and printed circuit board contact portions 684 interconnected to throughholes 686 on the printed circuit board 670. Electrical terminals 690 are also electrically mounted to printed circuit board 670 and include opposing blade-style contacts 692. Control board 448 can also be provided with electrical components generally shown at 694 to define any desired functions, such as an over current protection. While not specifically shown, it should be appreciated that the various components are interconnected to the electrical connector, for example, by electrical traces positioned on the printed circuit board and interconnected to plated throughholes 686. Thus, input-output to pin terminals 682 can control brushes 672, 674, to control the electro-magnet, and input current to terminals 690, to control the motor.

[00101] With respect now to Figure 50, motor assembly 408 is generally comprised of an electric motor 700 having an output shaft at 702 and electrical tab terminals at 704. A floating coupling is included at 706 having a split bearing 708, which is received over end 710 of gear 712. Drive end 714 of gear 712 is driven by hexagonal opening 716 of coupling 706, and shaft end 718 of gear 712 receives a bearing 720. With all the various components now described, the assembly of the actuator will now be described.

[00102] As mentioned above, main housing portion 404 is molded such that shaft 416 is integrally molded therein. Splined end 652 (Figure 47) of shaft 416 is integrally molded within the hub portion 486 (Figure 8) to be integrally fixed therein. This defines the housing portion 404, as shown in Figures 36 through 38.

Cover portion 446 is also molded to define the cover as shown in Figures 39 and 40. With respect now to Figures 42 and 45, rotor assembly 430 will be described.

[00103] As mentioned above, outer ring gear 580 is integrally molded over rotor 540 to encapsulate the radial ribs 544. Bobbin member 426 is now positioned within the cavity portion 550, ensuring that the winding ends 624 extend through slot 546. As best shown in Figure 45, slot 546 aligns with one of the apertures 592, and therefore contact ring assembly 437 is positioned relative to the assembly, such that contact ring contact 612 aligns with slot 546. This allows contact ring 602 to be interconnected to one of the windings 624 by way of the contact portion 612. It should be appreciated that contact portion 612 could include any well-known terminating portion, such as a magnet wire electrical contact, or any other suitable contact. Thus, both contact rings 421 and 437 are snapped in place, as described above, locking the rings 421 and 437 to the ring gear 580 and with each of the contact rings 602 interconnected to terminating wire ends 624. This contact is best shown in the cross-sectional view of Figure 54.

[00104] Rack 412 (Figure 52) is now received in the rack slide 410 (Figure 35) and first clutch plate 420 is positioned over shaft 416. This allows gear 634 to mesh with the rack teeth of rack gear 412. This engagement is shown best in Figure 52. Snap ring 423 is now positioned within its groove 654 (Figure 36) and washer 425 is placed over the shaft on the back side of snap ring 423. Rotor assembly 430 is now positioned over shaft 416, with hub portion 540 (Figure 42) being positioned adjacent to rear face 636 of first clutch plate 420. Thrust rods 432 are now positioned in the throughbores 556 (Figure 45) and are projected inwardly until they contact the backface 636 of first clutch plate 420. Snap ring 436 is now assembled over shaft 416 in its associated groove 656 (Figure 56), thereby axially retaining the rotor assembly 430 on shaft 416. Second clutch plate 442 may now be slidably received over shaft 416 and thrust washer 444, flanked by thrust washer 445 is positioned over hub portion 647 (Figure 43).

[00105] Control board 448 is now positioned in housing 404, such that brushes 672, 674 (Figure 49) are positioned adjacent to their associated contact portions 602 (Figure 42). This also positions contact portions 690 adjacent to

bearing wall portion 452. The motor assembly 408 can now be positioned into its associated receiving section, as described herein.

[00106] As shown in Figure 51, the motor assembly 408 can be received in a straight downwardly position, with the assembly 408 received in the housing 404. Motor 700 is positioned in its associated cavity, with drive sleeve 706 positioned within its opening 456, bearing 708 positioned in its opening 458, gear 712 positioned in its opening 460, and end bearing 720 positioned in its opening 462. This positions the outer helical gear of 712 in meshing engagement with the teeth of ring gear 586. Furthermore, with the motor 408 installed as described, tab terminals 704 extending from motor 700 are received in their associated contacts 690 of the printed circuit board 670. It should also be appreciated that the pin contact portions 682 (Figure 49) would be positioned in opening 484 and profiled for interconnection with a mating electrical connector.

[00107] The device is now assembled as shown in Figure 51, and a further thrust washer 445 (Figure 41) can be placed over the compression spring 444 and cover 446 placed over the assembly. Screws such as 750 can be positioned through bosses 530 of cover portion 446 (Figure 39) and be received within threaded openings of bosses 480. Finally, a bowden cable assembly 414 (Figure 52) is received in a slotted opening of rack 412, and a cover plate 752 is received over opening 754 (Figure 37) and fixed thereto. In this embodiment, the cover 752 is ultrasonically welded to opening 754. This positions bowden cable interconnected to the rack but projected through opening 756 (Figure 35) of rack slide 410. With the actuator as assembled, the operation will now be described with respect to Figures 53A and 53B.

[00108] Figure 53A shows the device in the normally operated position, where the magnet is not energized. In this configuration, compression spring 444 causes a thrust against second clutch plate 442, causing a spacing between clutch plate 442 and inner surface 522 of cover 446. This prevents the engagement between lugs 642 and apertures 524 and at the same time, causes engagement between lugs 570 and 648. The thrust of compression spring 444 against clutch plate 442 also causes the movement of thrust rods 432 within the

rotor, pushing against first clutch plate 420, preventing engagement between their corresponding interlocking lugs 562 and 638. Thus, when gear 712 meshes with ring gear 580, the output is to gear 644 by way of a rotary output.

[00109] However, if a linear output is required, electromagnet is energized, causing the magnetic attraction between first clutch plate 420 and ferromagnetic rotor 540, causing the inter-engagement between respective lugs 562 and 638, as shown in Figure 53B. At the same time, the movement of clutch plate 420 causes movement of thrust rods 432 against clutch plate 442, compressing spring 444 and disengaging interlocking lugs 570 and 648, while at the same time engaging lugs 562 and 638. Thus, driving gear 712 against ring gear 580 causes the rotation of the second clutch plate 420, which drives rack 412 and resultantly bowden cable 414.